EXHIBIT P

HANDBOOK OF COMPUTER VISION AND APPLICATIONS

Volume 1
Sensors and Imaging

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ACADEMIC PRESS

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17.1 Definitions

17.1.1 Camera calibration

Camera calibration in photogrammetric parlance refers to the determination of the parameters of interior orientation of individual cameras. When using digital cameras, it is advisable to analyze the complete imaging system, including camera, transfer units and possibly frame grabbers. The parameters to be found by calibration depend on the type of camera used. Once the imaging system has been calibrated, measurements can be made after the cameras have been duly oriented.

17.1.2 Camera orientation

Camera orientation usually includes determination of the parameters of exterior orientation to define the camera station and camera axis in the higher-order object-coordinate system, frequently called the *world coordinate system*. This requires the determination of three rotational and three translational parameters, that is, a total of six parameters for each camera.

17.1.3 System calibration

In many applications, fixed setups of various sensors are used for measurement. Examples are online measurement systems in which, for example, several cameras, laser pointers, pattern projectors, rotary stages, etc., may be used. If the entire system is considered the measurement tool proper, then the simultaneous calibration and orientation of all the components involved may be defined as *system calibration*.

17.2 Parameters influencing geometrical performance

17.2.1 Interior effects

All components of a digital imaging system leave their marks on the image of an object and thus on the measurement results obtained from processing this image. The following is a brief description of the relevant components (Fig. 17.1).

Optical system. Practically all lenses exhibit typical *radial-symmetrical distortion* that may vary greatly in magnitude. On the one hand, the lenses used in optical measurement systems are nearly distortion-free [1]. On the other hand, wide-angle lenses, above all, frequently exhibit distortion of several 100 μm at the edges of the field. Fisheye lenses are